THE NEW RAIL TECHNOLOGY SYSTEM FOR BHP BILLITON IRON ORE
A CASE STUDY

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SUMMARY

BHP Billiton Iron Ore is one of the world’s leading suppliers of iron ore products, shipping millions of tonnes of ore to steel mills around the globe. Strong worldwide demand for iron ore, particularly from China, has opened up greater opportunities to increase sales, stimulating an increased demand in capacity throughput of the whole system. BHP Billiton Iron Ore’s operations of extracting, processing and transporting iron ore from several mine sites in the Pilbara region of WA involves a complicated and integrated delivery chain of Mine-Rail-Port. With the aim of improving the delivery capacity of the rail system connecting the mines to the port, Siemens has been engaged to design and deliver a Rail Technology System (RTS).

This paper will give an overview of the RTS currently being developed for BHP Billiton Iron Ore on the basis of the Siemens Vicos®OC501 system and Falko® scheduling system. It will firstly outline the RTS system configuration. The main emphasis of this paper, the Train Control System (TCS) will then be described in greater detail, in particular, outlining the system architecture and the key operational functions being implemented. The final part of this paper will focus on the Train Information and Management System (TIMS) and the Intelligent Train Scheduling System (ITSS), briefly describing the capabilities currently being developed for the specificities of the RTS project.

In summary, it is anticipated that the RTS will expand BHP Billiton Iron Ore’s railroad delivery capacity, through a higher degree of automated operation, greater flexibility in scheduling and improved management of disruptions in daily operations.

BHP Billiton Iron Ore Railroad in the Pilbara Region – Short Description

BHP Billiton Iron Ore operates two heavy haulage railroads to Port Hedland; firstly, the Newman line, running 426 km from the Newman, Yandi and Mining Area C mines, and the second, Goldsworthy line, runs 210 km from Yarrie & Nimmingarra mines. The Newman line terminates at a large marshalling yard located at Nelson Point in Port Hedland. The Goldsworthy line terminates in a smaller yard located at Finucane Island, Port Hedland. Nelson Point has a number rotary dumpers to unload the iron ore from the ore cars, whilst Finucane Island has a single bottom-dump dumper with the building of an additional rotary dumper underway.

The Newman line is fully signalled and track circuited, allowing for remotely centralised traffic control. Many of the yard roads also have remote controllable switches which are track circuited in order to provide track occupation indications to the train controller.

The line to Goldsworthy is track circuited to facilitate the operation of the automatic train protection which operates in this area. The signalling safe working system is based on paper train orders.

Both lines are equipped with AEI tag readers, HotBox detection units and a weighbridge, as well as a wheel impact monitor. All of these systems gather valuable data required for the safe working of the entire Mine-Rail-Port operation in the Pilbara region.

INTRODUCTION: RAIL TECHNOLOGY SYSTEM

In March 2005, Siemens was awarded the contract to design, install and commission the Rail Technology System (RTS) for BHP Billiton Iron Ore (in the rest of this paper referred to only as BHP Billiton). The RTS for BHP Billiton incorporates three integrated elements – a Train Control System, an Intelligent Train Scheduling System, and a Train Information Management System. This paper will examine each of these three elements in turn.

Firstly, the new Train Control System (TCS) allows BHP Billiton operators real-time control of the rail freight movement of the entire system. The system offers standard train control functions such as train tracking and monitoring, manual route setting and blocking, alarm management facilities, automatic route setting and an electronic based train order function for the Goldsworthy line.

Secondly, the Train Information Management System (TIMS) is a large database, collecting internal operational data from the TCS and ITSS, as well as data from external sources, including track side mounted equipment such as the AEI tag and HotBox data. The accumulated data can be
reorganised and collated for flexible data combinations, user queries, and the generation of various management reports.

Thirdly, the Intelligent Train Scheduling System (ITSS) is based on the Siemens Falko scheduling tool. The ITSS interfaces to BHP Billiton’s external legacy system (SAP) to download the iron ore capacity requirements for a defined period of time. The capacity requirements will then be matched with the availability of infrastructure and rolling stock to generate a daily master timetable. Furthermore, within the ITSS, additional functions are available to optimise the train control process, including the generation of electronic train graphs and online scheduling. These tools enable flexible control, whilst allowing the operator to make informed decisions and react immediately to changed events as they arise.

**PROJECT APPROACH**

The RTS project will be designed, installed and commissioned in two stages. Stage 1 will replace the existing train control system for the Newman and Goldsworthy mainline operations, excluding the yard operation, with the same functions as currently exists, enabling operations to continue throughout the implementation of the RTS. Where feasible, within the short implementation time for Stage 1, additional functions enhancing operational use will be implemented.

During Stage 2 the RTS system will be rolled out across the entire railroad including the marshalling yards. During this stage the full train control and online scheduling functions will be added.

This step-by-step introduction of the new system was selected to reduce the implementation time in order that benefits would be obtained for BHP Billiton in the interim period. This implementation strategy also minimises the risk of interface disjunction, as these interfaces are continually being refined and adjusted at each stage of the project. Importantly for BHP Billiton, the stage approach limits the possible interruptions of daily business to a controllable level, while still delivering a substantial change and modernisation of the railroad system.

**NOTATION**

RTS = Rail Technology System  
TCS = Train Control System  
ITSS = Intelligent Train Scheduling System  
TIMS = Train Information Management System  
Vicos®OC 501 = Vehicle Infrastructure Control Operating System  
Falko® = TimeTable Management System (FAhrpLan KOnstruktion)  
COM = Communicator  
ADM = Administrator  
MMI = Man Machine Interface  
IFS = Independent Front-End System  
RTU = Remote Terminal Unit  
OCC = Operation Control Centre  
BCC = Backup Control Centre  
TRC = Training and Reply Centre  
DC = Development Centre  
SOLARIS = UNIX Operating System  
RDBMS = Real Time Data Base Management System  
IPC = Inter-processor communication  
AEI tags = Automatic Equipment Identification  
BaSiWi = Basic Signalling Window  
ARS = Automatic Route Setting  
A&L = Alarms and Logs  
TMT = Train Monitoring and Tracking  
IC = Interlocking Control  
P&R = Playback and Replay  
MF = Maintenance Function  
TOF = Train Order Function  
ATP = Automatic Train Protection
**RTS SYSTEM CONFIGURATION**

The total RTS system consists of the Operation Control Centre (OCC), Backup Control Centre (BCC), Training and Replay Centre (TRC) and the Development Centre (DC). A diagram of the system configuration is provided in Appendix A.

The OCC and BCC are connected via a redundant 100 Mbit/s Ethernet LAN, based on the TCP/IP communication protocol. In case of an emergency in the OCC, the BCC will take over the operation of the entire railway, as it offers the operator the same functions as the OCC.

The TRC is used for operator training, post-event analysis and evaluation of incidents. The functions and set-up of the TRC is explained further within the Train Control System section of this paper.

The DC will be used for on-site reconfiguration of the system in case of railway expansion and modification to the existing rail infrastructure.

This paper will now explain in greater detail each of the three integrated elements of the BHP Billiton RTS – the Train Control System (TCS), the Intelligent Train Scheduling System (ITSS), and the Train Information Management System (TIMS).

A greater emphasis is placed on the TCS as, at this stage of the project design phase, this component is the most developed.

**TRAIN CONTROL SYSTEM**

The TCS system is based on the proven Siemens Vicos®OC501 platform, which was specially developed for the operations of mainline railways, subways and industrial railways. The system software is based on the Siemens Scada SINAUT®Spectrum and Oracle®RDBMS software packages. The TCS is based on the UNIX operating system SOLARIS.

**Software Architecture**

The Vicos®OC501 splits up the control systems tasks into functional modules, which can be freely distributed among the hardware components. Figure 1 illustrates such a distributed network model, where basic functions run on all servers connected to the LAN (black coloured boxes in Figure 1) and other modules can be assigned to a specific server(s) (white coloured boxes). The distributed system architecture enables the system to perform a number of functions simultaneously. The separation of process-critical and non-process critical functions on different servers, ensures that the process critical functions can always be executed with the highest priority and maximum processor capacity.

An additional advantage of splitting up the software into function modules is the ability to add new functions, develop existing functions or extend the network capacity. This is demonstrated in Figure 2. The inner red marked modules in Figure 2 form the core system and are non-project specific and are therefore not altered during the engineering process. These core modules are comprised of the SINAUT Spectrum, Oracle RDBMS and the Inter-Processor Communication software modules.

The green marked modules are project specific. While based on standard train control functions, each of these modules can be modified and adapted on a project-to-project basis in order to comply with individual customer or railway operating rules and specifications. The following function modules are included in the BHP Billiton RTS system for Stage 1:

- Alarms and Logs (A&L)
- Train Monitoring and Tracking (TMT)
- Interlocking Control (IC)
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- Playback and Replay (PR)  
- Maintenance Function (MF)  

The yellow marked modules will be implemented into the RTS during Stage 2 and are listed below:  
- Automatic Route Setting (ARS)  
- Train Order Function (TOF)  
- TimeTable Manager (TTM)  

The outer blue circle represents individual interface modules to internal and external systems. These may be based on standard protocols or developed according to specific customer requirements. For the BHP Billiton RTS the specific protocols included are the following:  
- Distributed Network Protocol (DNP3)  
- Westinghouse based S2 Protocol  
- Southern Technology Cooperation  
- Internal Interface to the TIMS  
- External Interface to the Wheel Impact Monitor

TCS System Architecture

The main TCS system consists of the following hardware components:  
- 10 MMI servers  
- 2 Maintenance MMI servers  
- 2 IFS servers  
- 3 COM servers  
- 2 ADM servers  
- Ethernet peripherals  
- Printers

The functions and design of each of these components will be described in further detail below. The TIMS will be explained separately later in the paper; however, it is integrated within the TCS system architecture.

Man Machine Interface (MMI)

The MMI is the main interface between the operator and the RTS system in the control centres. The operator console for the RTS contains a SUN workstation, four 24" flat screen colour monitors plus two additional 20" flat screen colour monitors, an alphanumericical keyboard and a mouse. A principle representation of the planned workstation is outline in Figure 3 below.

The RTS system is operated using the mouse and keyboard. The different functions can be activated by selecting an icon via “drag and drop” from the toolbar. Several windows can be opened at the same time and moved around the screen as required or preferred by each individual operator. The multiple window method allows several system functions to be performed simultaneously.

The MMI server provides the following functions:  
- Rail Network Views  
- Control Functions  
- Maintenance Function (only available on a Maintenance MMI)  
- Administrative Function  
- Message and Alarm Logs  
- Special Operations  

The function and their use are explained in more detail within the section on Operating Principles. However, the scope of detail is limited to a level appropriate to the depth and length of this paper.

Communicator (COM)

The COM server is the actual process computer and the heart of the system. The “process image” is stored on this server and all external information acquired from the telemetry and other external interfaces are also processed on the COM. The automatic train control operations and control functions, such as the Train Monitoring and Tracking, Automatic Route Setting, etc, run on these servers and can be controlled by the operator via the MMI.

The COM performs the following functions:  
- Processing of data transmitted from the interlockings and other subsystems via the IFS  
- Output of commands to the interlockings via the IFS  
- Train Monitoring and Tracking  
- Storage of the daily operations log and alarm lists and  
- Recording of all process data necessary for later playback.

Administrator (ADM)

All static system data and application software is stored on the ADM server. This computer stores all data that belongs to the system and will normally not be modified during operation, such as the track layout and other configuration data.

When the system is powered up, when a request has been made or when configuration data has been modified, all other servers in the network are updated automatically online with the data provided by the ADM.

Figure 3 Principle representation of the RTS workstation
Furthermore, an archiving system is located on the ADM as well. During operation all relevant operational data is stored and can be requested via the MMI-servers.

**Independent Front End System (IFS)**

The IFS server is the RTS subsystem which serves as the connection between the TCS and the external subsystems. It is a universal process interface, based on UNIX servers. The IFS is implemented as a redundant server pair, which communicate with the other servers of the Vicos system via the LAN. The RTUs will be connected with a multidrop connection, whereby the line from the RTU, once divided via a line splitter, connects with both of the IFS servers, as demonstrated in the Figure 4 below.

![Figure 4: Independent Front-End System](image)

**Other components**

Additionally, A3 printers and a plotter are connected to the LAN. A radio controlled clock system is used as the time reference source for the RTS.

**TCS Redundancy Concepts**

Three types of redundancy are used:

- For the COM servers: hot-standby redundancy with delay-free changeover
- For the ADM servers: spare redundancy with automatic changeover
- For the MMI servers: substitute operation without automatic changeover

**COM Hot Standby Redundancy**

The three COM servers are identical regarding their hardware and software, two active in hot-standby mode and one in cold-standby (refer to RTS configuration, Appendix A). The two COM servers in hot-standby mode are working in parallel; however the non-process-controlling server suppresses its outputs. If the process-controlling server fails, the standby server can take over the process management immediately, as it is also processing the current operational data. The switchover time is less than one second and will not have any impact on operations. During the repair of the failed server the third COM, running in cold standby, can be activated into the hot-standby mode. Once the failed server has been repaired, it starts up in the cold standby mode.

**ADM / Spare ADM Redundancy**

If the active ADM server fails in operation, the spare ADM will start the run-up procedure and will take over the ADM function once active. The switchover from the ADM to the Spare ADM will not cause any loss of reporting data, since for the down time of the ADM the data will be stored in a buffer on the COM.

![Figure 5: ADM Spare Redundancy](image)

**MMI Redundancy**

The MMI servers provided for the central control in the OCC are all identical. This means that one MMI is able to take over the functionality of another MMI. Usually, a specific operating area is assigned to each of the MMI servers for monitoring and control of the operating process.

If one MMI server fails, the responsibility for the operated interlocking area can be assigned to another MMI server.

![Figure 6: MMI Change-Over of the MMI Servers](image)
OPERATIONAL FUNCTIONS OF THE TCS

After the operator has logged onto the MMI the active authorisation and responsibilities of the operator are then assigned to the current workstation and the operator is presented with the Basic Signalling Window (BaSiWi) as illustrated in Figure 7. The BaSiWi illustration is the first prototype for Stage 1 and while changes in format and style are possible, the main functions that can be accessed via the BaSiWi will remain. Additional functions will be added for the final RTS system.

The operator uses the BaSiWi to drive and operate the system, by clicking on the relevant icon and then using a “drag and drop” motion to place the operating window on the available screens. The following MMI functions can be opened from the BaSiWi:

<table>
<thead>
<tr>
<th>Icon</th>
<th>Operational Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail Network Views</td>
<td></td>
</tr>
<tr>
<td>MLO</td>
<td>Main Line Overview</td>
</tr>
<tr>
<td>GEO</td>
<td>Geographical Overview</td>
</tr>
<tr>
<td>SYS</td>
<td>System Overview</td>
</tr>
<tr>
<td>Control Function</td>
<td></td>
</tr>
<tr>
<td>TMT</td>
<td>Train Monitoring and Tracking</td>
</tr>
<tr>
<td>IC</td>
<td>Interlocking Control</td>
</tr>
<tr>
<td>Maintenance Function</td>
<td></td>
</tr>
<tr>
<td>IFS</td>
<td>IFS Status and Control</td>
</tr>
<tr>
<td>ILD</td>
<td>Interlocking Diagnostics</td>
</tr>
<tr>
<td>STC</td>
<td>STX Set-up Data Dialogue</td>
</tr>
<tr>
<td>SDM</td>
<td>Source Data Management</td>
</tr>
<tr>
<td>Administrative Function</td>
<td></td>
</tr>
<tr>
<td>A&amp;R</td>
<td>Authority and Responsibilities</td>
</tr>
<tr>
<td>UAC</td>
<td>User Administration Control</td>
</tr>
<tr>
<td>R&amp;P</td>
<td>Record and Playback</td>
</tr>
<tr>
<td>Message and Alarms logs</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Alarm Log</td>
</tr>
<tr>
<td>B</td>
<td>Warning Log</td>
</tr>
<tr>
<td>C</td>
<td>Notification log</td>
</tr>
<tr>
<td>CD</td>
<td>Operation Diary</td>
</tr>
<tr>
<td>OL</td>
<td>Manual Operations</td>
</tr>
<tr>
<td>Special Operations</td>
<td></td>
</tr>
<tr>
<td>CAM</td>
<td>Screenshot</td>
</tr>
<tr>
<td>WEB</td>
<td>Web browser</td>
</tr>
</tbody>
</table>

Below some key examples, outlining the attributes of the main functions accessed through the BaSiWi, are described.

Rail Network Views

The Rail Network Views can be accessed through clicking on the “MLO”, “GEO” or “SYS” icon at the left of the BaSiWi. For this paper, the GEO view provides an example of the operation and capabilities of the View functions. The GEO view, (Figure 8) can be placed freely on the available desktops, resized, minimised, maximised, closed or reopened.

The operator can then navigate from the GEO view to the defined Control Area views or directly to the Station views. This navigation principle is outlined in Figure 9. The operator can navigate between the different views using a range of navigation buttons. A number of zoom options are also available to the operator. Figures 10 and 11 show prototype representation of the different control areas and station views.

Below some key examples, outlining the attributes of the main functions accessed through the BaSiWi, are described.
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The Station views (Figure 11) add all collective indications from the interlockings and HotBox detection units.

In addition to the GEO overview, the Main Line Overview (MLO) shows the entire railroad as one view with exception of the marshalling yard.

The System Overview (SYS) displays the current status of the Vicos servers, printer states and LAN connection states for information only.

Control Functions

The control functions briefly described here will be implemented during Stage 1 of the BHP Billiton RTS. These functions are accessed through the second set of icons along the BaSiWi.

Train Monitoring and Tracking (TMT)

The TMT monitors and manages the movements of all rolling stock, such as trains, locos, ore cars, track machines and Hi-rails, for the supervised area. The locations of the trains are determined with the help of field equipment. Figure 12 illustrates the TMT operator interface, which can be opened via the BaSiWi or directly by clicking on the Train ID symbol on the relevant overview screen.

The TMT function offers the operator a range of options, including change of train ID, manual stepping or reordering of trains and deletion of train trips.

Interlocking Control (IC)

The IC function can be selected in the same manner as the TMT function. A number of different windows are available to the operator depending on the selected element, such as signals, switches, tracks or interlockings. The operator selects the element(s) by clicking on the symbol icon in the various overviews. The example in Figure 13 shows the operational options presented to the train controller for a switch that has been selected via a simple mouse click. Here, the operator can easily select the desired action, be it to reverse, block or unblock the switch. The status of the switch is indicated by a colour coded system.

Similar commands can be executed for the signals, tracks, ATP nodes and route-setting function, in the same manner as was demonstrated by the switch example above.

Maintenance Functions

Two functions, the IFS Status and Control Diagnostics and the Interlocking Diagnostics (ILD), are being developed for controlling, maintaining and managing the external interfaces. Both of
these Maintenance Functions are accessed through the BaSiWi.

**IFS Status and Control Diagnostics**

The IFS window supplies the operator with status and controls for the RTUs and channels connected via the IFS block function.

All IFS Status and Control operations are enabled only if the user has the maintenance ("MAINT") authorisation. The maintainer can enable or disable communication with individual RTUs, or they can enable or disable communication with all RTUs connected to one communication channel. Furthermore, the maintainer can easily force a link switchover of the channels between the IFS servers.

![IFS Status and Control Window](image)

**Figure 14: IFS Status and Control Window**

**Interlocking Diagnostics (ILD)**

The ILD window provides the maintainer an overview of the current communication set-up and polling performances of the IFS and RTU link. It displays the last received indication bits and provides statistics of the successful polls to and from the RTUs.

![Interlocking Diagnostics Window](image)

**Figure 15: Interlocking Diagnostics Window**

**Administrative Functions**

**Authorisation and Responsibilities (A&R)**

The RTS differentiates between operator authorisation, workstation specific authorisation and workstation specific responsibilities. For the RTS system the following user groups have been defined:

- System Administrator
- Supervisor
- Controller
- Maintainer
- View Only User

The operator-specific authorizations are assigned during the Login procedure via the operator name and the password. The system administrator can then select the A&R function and will be presented with the following window (Figure 16).

![Authorisation and Responsibilities](image)

**Figure 16: Authorisation and Responsibilities**

The change of the assignment is carried out by using the mouse to place ticks in the appropriate boxes, as is represented in Figure 16. A handover procedure is in place to acquire or to offer the responsibility for one or more control areas.

**Record and Playback (R&P)**

The main task of the R&P is to record all events on the online system and play them back on the replay system located in the Training and Replay Centre. The aim is to enable BHP Billiton to analyse critical events that occurred in the past. The contents of the track overview, the system overview and the message and alarm lists are reproduced when a recording is played back. The playback faithfully reproduces the original timing of the events.
To playback recorded events and activities the desired starting and end time have to be entered into the Start and End text fields of the R&P Playback Window, illustrated in Figure 17 above. By clicking the “Init” button of the R&P Window the data is loaded and the playback can start. The playback speed can be adjusted and the playback can be stopped or paused at any time.

Messages and Alarm function

The message and alarm function registers and records all state changes (alarms and events) from within the TCS system and the external interfaces. The state changes are recorded as “Message Texts” (messages) in separate lists and the following five categories can be accessed by the operator via the BaSiWi:

- A – Alarm Log
- B – Warning Log
- C – Notification Log
- OD – Operating Diary
- MO – Manual Operation

The Class A Alarms list contains alarm messages that the user should be made aware of immediately. When an alarm is entered into this list it is accompanied by an acoustic signal and flashing of the List button on the BaSiWi. Typically the messages in this list require an acknowledgement operation by the train controller. The proper acknowledging of the message results in the audio tone and the List button will stop flashing.

The Class B Alarms (Warnings) list contains alarm messages of a lower priority than those entered in to the Class A Alarms list. A separate acoustic signal of lower priority will be issued for messages entered into this list.

The Class C Alarms (Notifications) list contains the messages that inform the operator that a routine event has occurred. Once the message has been acknowledged the message is removed from the list.

The Operation Diary contains a copy of all of the messages entered into the Class A, B and C Alarms lists that have been generated. Messages in this list cannot be acknowledged. All users regardless of their Control authority have access to view this list.

The Manual Operation list contains all user operations. The messages entered in the list are not acknowledgeable. All users regardless of their Control authority can view this list.

Operational Functions - Stage 2

In principle, three major function blocks will be added to the BHP Billiton RTS during Stage 2. Primarily, these are an Automatic Route Setting (ARS) function, an electronic-based Train Order Function (TOF) and finally a TimeTable Manager (TTM) function (indicated by the yellow modules in Figure 2, page 3) Brief descriptions, outlining the basic operations of the ARS and TOF functions, are provided below. During Stage 2 design and implementation, these function modules will be modified and adjusted to complement the RTS requirements. The TTM function is elaborated further in the section regarding Intelligent Train Scheduling System (ITSS).

Automatic Route Setting (ARS)

The ARS is a function that automates the setting of train routes. The operator is largely relieved of the standard operator actions. Its function is to generate interlocking commands based on the current train locations and the timetable data.

The ARS is initiated by a train location indication. Additional criteria, such as operational trigger points will be taken into consideration in order to process operational irregularities. In certain cases, the ARS can only set the route when the timetable departure time has been reached. The route will be determined from the destination code and location of the train to be controlled.
Train Order based Function

Currently, the safe working system at BHP Billiton for train workings on the Goldsworthy line involves paper-based Train Orders. In Stage 2 of the implementation of the final RTS, the existing system will be replaced by an electronic based function within the TCS.

The operator will still need to pass the Train Order information to the locomotive driver by radio. The locomotive driver will also confirm this Train Order via the radio. All commands, proceeding points and confirmations will be recorded electronically and displayed on the overviews. Therefore, the transfer between signalled and non-signalled control areas will be seamless for the operator. Before issuing a new Train Order for a section, the system will alert the operator of any significant conditions, such as an occupied track or active Train Orders in the section to be protected by the new Train Order.

Summary - Operations Functions

The Rail Network Views, Control, Maintenance and Administrative Functions, as well as the Message and Alarm Logs are all operational functions within the TCS. As illustrated, each is accessed easily through the icons group along the BaSiWi.

The Stage 1 functions are currently being designed and implemented, with the aim to have installation and operations active as soon as is feasible. These Stage 1 functions will then be further extended and enhanced during Stage 2. Additionally, the systems functions will be advanced through the implementation of the ARS, TOF and the full functioning TIMS and ITSS. The TIMS and ITSS will now be explained in greater detail, however, these developments are still in the early design and engineering processes and can only be seen as conceptual outlines.
TRAIN INFORMATION AND MANAGEMENT SYSTEM (TIMS)

The TIMS server is a data warehouse based on an Oracle database, which is integrated into the RTS configuration (see Appendix B). The main function of the TIMS is to store, manage and analyse train-related information that is generated internally in the Vicos system and externally from the equipment installed in the field. The data to be handled includes the train running data, HotBox data, AEI tags and weighbridge data. Additionally, the TIMS performs a temperature trending analysis of the received HotBox data and an analysis of AEI tags.

For Stage 1, the TIMS is planned to include the following functionality:

- Storing train related data from TMT in a database
- Issuing alarms
- Replacing of missing AEI-tag data
- Providing a web browser to access external screens
- Transfer of train running data, hotbox data, AEI data and weighbridge data to the external systems

To highlight two of the functions intended for the TIMS, the HotBox Alarms and AEI tag functions are elaborated here.

HotBox Alarms

It is anticipated that two kinds of alarms will be generated by the TIMS, where the first type is issued directly by the HotBox detection unit. This alarm is raised if a set threshold is exceeded. The alarm data about the event, train ID and AEI tag of the relevant car is captured via the IFS, stored and distributed by the TIMS. If a HotBox alarm is detected the relevant alarm list is updated and alerts the operator.

Furthermore, the aim of the TIMS is to process and analyse the HotBox data in order to detect preheating or a fault prior to its occurrence. For a configurable time frame the temperature data for each wheel/bearing will be recorded. Figure 19 is a principle representation of the trending analysis.

AEI tags

During a train run on various points in the network the AEI tag information of the locomotives and cars are collected and sent back to the RTS system. During these trips it can happen that one or more AEI tags are read incorrectly and are therefore recorded as missing. The missing AEI tags are automatically replaced by the field equipment with a random number that differs from the AEI tags. The TIMS aims to store all received AEI tag telegrams and apply an algorithm that replaces the random number with the missing AEI tag. An algorithm will be developed which looks at the predecessor, successor and all previous values of the missing tag in order to replace the equipment-generated number with the correct AEI tag.

TRAINING AND SIMULATION (T&S)

The RTS also includes Vicos T&S software, which simulates the outdoor equipment and interlocking behaviour of the BHP Billiton railway operation in the Pilbara. The trainee is presented with an identical workstation to the online RTS, with the trainer using the T&S workstation and interface to drive the training session. The trainer has the option to execute predefined scenarios or test the student response after a failure has been initiated in the T&S system. Figure 20 outlines a principle representation of the T&S screen.
INTELLIGENT TRAIN SCHEDULING SYSTEM (ITSS)

The anticipated ITSS will be divided into two components, ITSS-Offline and ITSS-Online, and will be based on the Siemens Falko Scheduling System.

Firstly, the offline ITSS component will be used to generate and optimise all planned schedules (timetables) for each individual day of operation. These schedules will be derived from production orders for the days of operation ahead. In addition, the offline ITSS seeks to provide the user with editors to modify planned schedules and track topologies.

The second component, ITSS-Online, receives the planned schedules from ITSS-Offline, converts them into running schedules and controls their automatic operation. For this, the online ITSS has a connection to the central TCS components, TMT and ARS, via the Vicos TimeTable Manager module (TTM). ITSS-Online provides an editor for adjusting running schedules (manual dispatching). It also includes functions to optimise running schedules during actual operation (automatic dispatching).

Falko Geo

Falko Geo is a simple graphical tool that enables the user to replicate the railroad track typology and runs on the ITSS-Offline server, displayed in the RTS configuration in Appendix A.

The track topology is entered using the user menu as shown in Figure 21. Tracks, switches and crossings are entered with all the necessary attributes such as track length, maximum permissible speed and track gradient.

For the modelling of the interlocking logic, additional objects such as signals, routes, overlaps and insulated rail joints are inserted in the model. Figure 22 is a primary illustration of the track topology model currently being developed for the RTS project using the Falko Geo tool. In addition to the standard signalling elements, new elements, such as iron ore loaders, dumpers and handover points must be developed, in order to simulate the complete transport tasks of the BHP Billiton RTS.

A number of analysis functions can be used to check the correctness of the topology model. Finally, the editor exports the model to the Offline component of the ITSS.

Falko Offline

Falko Offline imports the production orders for a defined period of time and downloads the maintenance planning data for the rolling stock and track. The scheduler can additionally define speed restriction sections or block a track section for a period of time. Once the basic data is defined the scheduler runs the routing function, which will generate the operative timetable and resolve all meet/pass conflicts and adjust the trip start times automatically. Typically, Falko Offline can be used for three basic scheduling applications.

- Daily planning: generating a schedule for a specific day which is to be used in the online system
- Master planning: generating schedules for predefined setting/scenarios
- Capacity planning: determining the most efficient order plan which can be executed without capacity violations or major delays

Falko Train Dispatcher Interface (TDI)

Falko TDI displays the planned, running and actual schedules in form of a time distance diagram as shown in Figure 23. It offers the user an interaction option for manual or automatic dispatching. These options are currently being modified for the RTS project and therefore no detail of the method is provided in this paper.
In addition to the graphical user interfaces, the algorithmic applications are performed in the background, by Falko Online ITSS. This online component converts the planned schedules into running schedules. The TDI is then updated with the new or modified running schedule. The online ITSS executes the dispatching commands initiated via the TDI. The dispatching can be entered manually or automatically generated by the online ITSS. Additionally, Falko Online ITSS exports all relevant train running data and timetable data to the TIMS for further data analysis.

Finally, the TimeTable Manager (TTM), running on the Vicos COM server, connects the TCS and Falko Online ITSS. The TTM receives the running schedules and sends back the train location to Falko Online ITSS received from the Train Monitoring and Tracking (TMT) module. The TTM also sends out the route setting commands to the ARS module.

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APPENDIX A

RTS SYSTEM CONFIGURATION
Training & Replay Centre (TRC)
Operation Control Centre (OCC)
Backup Control Centre (BCC)

Legend
- Component supplied for Interim and Final Solution
- Component supplied for Final Solution

DAS Component
TCS Component
TIMS Component
ITSS Component

BHP Billiton Iron Ore Rail Technology System

RTS System Configuration